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**Fitting the message to the location: engaging adults with antimicrobial resistance in a World War 2
air raid shelter**

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Running header: Engaging adults, AMR and WW2

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Abstract

Aims

There are many different initiatives, global and local, designed to raise awareness of antimicrobial resistance (AMR) and change audience behaviour. However, it is not possible to assess the impact of specific, small-scale events on national and international outcomes - although one might acknowledge some contribution to the individual and collective knowledge and experience-focused 'science capital'. As with any research, in preparation for a public engagement event, it is important to identify aims, and appropriate methods whose results might help satisfy those aims. Therefore, the aim of this paper was to develop, deliver and evaluate an event designed to engage an adult audience with AMR.

Methods and Results

The venue was a World War 2 air raid shelter, enabling comparison of the pre- and post-antibiotic eras via three different activity stations, focusing on nursing, the search for new antibiotics, and investigations into novel antimicrobials. The use of observers released the presenters from evaluation duties, enabling them to focus on their specific activities. Qualitative measures of audience engagement were combined with quantitative data.

Conclusions

The evaluation revealed that adult audiences can easily be absorbed into an activity- particularly if hands-on - after a brief introduction.

Significance and Impact of Study

This research demonstrates that hands-on practical engagement with AMR can enable high level interaction and learning in an informal and enjoyable environment.

Keywords

- Antibiotics
- Bacteriophages

- 48 • Biofilms
- 49 • Soil
- 50 • Resistance
- 51 • Adult Education
- 52 • Outreach
- 53 • Public Engagement

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Introduction

Antimicrobial resistance (AMR) is recognised as a global issue. There are several international initiatives designed to raise awareness and change behaviours of a range of stakeholders within pharma, agriculture, the medical, midwifery and nursing professions (WAAR, WHO) and the public (WAAW, Antibiotic Guardians). Others encourage researchers to address the challenges of diagnosis and discovery of new agents (<https://longitudeprize.org/>), to apply for focused funding (Kelly, Zoubiane et al. 2016) and to work with politicians and policy makers (egLeSPAR [www.bsac.org.uk/learned-societies-partnership-on-antimicrobial-resistance-lespar/]).

Children are the target audience for games such as e-bug (McNulty 2011), plays (<https://www.microbiologysociety.org/event/education-outreach-events/stopping-the-spread-of-superbugs-2012.html>) and hands-on activities such as the Small Worlds Initiative (Davis, Sloan et al. 2017) and Antibiotics Unearthed (<https://www.microbiologysociety.org/education-outreach/antibiotics-unearthed.html>). At family-focused events, adults tend to work with the scientists to engage their own children. Adults can also access public information through television and poster advertisements, events (eg science cafes), the news and other media (for example the television documentary Michael Mosley versus the Superbugs, www.bbc.co.uk, screened on 17 May 2017) and the BBC Radio 4 series Resistance by Val McDiarmid, first aired on 3 March 2017 [www.antibioticresearch.org.uk]), and participate in citizen science projects such as Swab and Send (<https://www.facebook.com/swabandsend/>). However, active engagement is less of a priority when adults are the intended audience.

Evidence for the success of campaigns and initiatives might be deduced from such newsworthy successes as the reduction in prescriptions for antibiotics (Wise 2016), or the decrease in MRSA infections (Duerden, Fry et al. 2015), but the impact of specific events on such outcomes is not easy to assess – although one might acknowledge some contribution to the individual and collective ‘science capital’ which has been used to describe a measure of engagement with science (www.kcl.ac.uk and www.transformingpractice.sciencemuseum.org.uk). It is important to make

critical evaluations of such events in order to inform and enhance any future activities. Quantitative data demonstrate reach (for example how many attended, how many participated). Other feedback sought at events tends to reveal that events are ‘interesting, informative and enjoyable’ (Verran et al., 2018; Redfern et al, 2018), rather than providing any critical or constructive comment. Even if asked to name ‘three things you have learned’, or similar, data acquired are still essentially quantitative/fact-based (Redfern et al. 2015). Evidence of impact of an activity on the audience requires more qualitative, descriptive evaluation around engagement and perception (for example, how do you feel about this, what are your thoughts?).

In a previous family-focused event designed to raise awareness of AMR, it was apparent that adults were keen to engage researchers in conversation, but their prime focus was the entertainment of their children (Redfern et al., 2018). As noted above, events are rarely designed to allow adults to get hands-on experience of laboratory science, in an informal environment with scientists. Therefore the aim of this paper was to develop, deliver and evaluate an event designed to engage an adult audience with AMR.

Materials and methods

Event venue

Stockport air raid shelters (<https://www.stockport.gov.uk/topic/air-raid-shelters>) are tunnels cut into the red sandstone cliffs that frame the Mersey valley which runs through the town. One of the tunnel networks is open to the public as a tourist attraction. Comprising almost one mile of tunnels, the site has capacity for over 6000 people to take shelter during air raids, but for conducted tours today, numbers are limited. The tunnels contain a range of real and replica ephemera, including toilets (not for use), a nursing station, an area for feeding mothers, a catering station, and racks of metal frames of bunk beds. There is also a blackout room, and a separate area where visitors gather prior to their conducted tour.

Stockport tunnels provided an ideal opportunity to explore AMR with an adult audience by revisiting the pre-antibiotic era (penicillin was made available for the troops fighting the Second World War, but because it was in short supply, it was not available for the civilian population, except in very rare circumstances as a ‘corpse-raising drug’ (Brooks, 2018)), and considering a ‘post-antibiotic era. The event was held as part of the 2017 Manchester Science Festival (<http://www.manchestersciencefestival.com/>).

Planning and delivery: Key messages

The team leaders (JV and JR) identified a series of questions for the audience that would frame the event. These were:

How important are antibiotics to us today?

How did we cope without them?

Can we find new antibiotics?

Can we develop alternatives to antibiotics?

Why is AMR an issue and what is being done to address it?

The full delivery team then identified activities that would engage the adult audience whilst addressing these questions.

How important are antibiotics to us today?

Audience members assembled in the meeting space (a tunnel with bench seating on either side, period posters and bunting), and were introduced to the museum, to AMR and the event by the lead author and the museum curator (fig 1). They were each provided with a ‘gingerbread man’ diagram (and a pen) and asked to mark areas of the body for which they had taken antibiotics (anonymously). The aim of this activity was to encourage reflection on the value of antibiotics in the treatment of

both superficial and systemic infection. The audience was divided into groups of ten, and each group was led into the tunnels proper by a guide. The diagrams were collected and data were pooled onto a larger 'gingerbread man' for viewing in the museum shop after the event. Leaflets encouraging sign up to the Antibiotic Guardian scheme (<http://antibioticguardian.com/>) were also distributed, along with information about the museum itself.

How did we cope without them?

At the tunnel nursing station, the groups listened to stories about the pre-antibiotic era, and the role of nurses in the treatment of infections and disease. Penicillin was seen as a miracle cure, as soldiers who previously could have succumbed to gangrene had their limbs saved, and were returned to battle. Penicillin was also invaluable against venereal disease (Bud, 2007; Harrison, 2004). Initially nurses thought that penicillin would make their expertise in infection management almost obsolete, but the involvement of nursing staff in the experimental stages of the introduction of a new technology was a new venture: nurses learnt alongside their medical colleagues, shifting boundaries between nursing and medical work and at times dispelling long-held professional hierarchies. The need for nurses to administer penicillin (intramuscular injections three hourly into the buttock for up to five days) also meant that they were needed at the frontline (Brooks, 2018)

Can we find new antibiotics?

The canteen area was ideal for some practical microbiology experiments, providing table surfaces to facilitate activities. In an introduction, visitors were shown a timeline adapted from Lewis (2013) revealing intensive activity over a relatively short time period when the majority of antibiotics were discovered and mass-produced. Now there are many initiatives whose aim is to identify potential new agents, with samples being taken from different environments for example caves (Pawlowski, Wang et al. 2016), the depths of the ocean (Zhang, Dong et al. 2017) and everyday sites (for example Swab and Send) and the Small World Initiative. After this introduction, visitors swabbed sites in the

tunnels in a search for antibiotic-producing microorganisms. Each visitor was provided with a moistened swab (only the presenter/demonstrator had access to liquid in the tunnel to minimise spillage risk) which they used to spread inoculate a malt extract agar and a tryptone soy agar plate (Oxoid, Basingstoke). Each plate was marked, and after incubation at the University (ten days at 30C to ensure sufficient mould growth), photographs were posted on Flickr (<https://flic.kr/s/aHsm5QBJR1>) for viewing and download. Visitors were also asked to select the names of bacteria that they had heard of before the event from the list of WHO priority pathogens for new antibiotic research and development (WHO 2017).

Can we develop alternatives to antibiotics?

This station, using the blackout facility, provided an opportunity for researchers to describe some of their relevant work (<https://www2.mmu.ac.uk/shs/research/microbiology/>). From a range of topics including phage therapy (e.g. Alves, Gaudion et al. 2014), repurposing of anti-cancer and other drugs (e.g. Southam, Butler et al. 2017), antimicrobial metals (e.g. Redfern, Goldyn et al. 2017), natural antimicrobials such as essential oils (Kinninmonth, Liauw et al. 2013), graphene as a delivery tool (Whitehead, Vaidya et al. 2017), antimicrobial surfaces and surface hygiene as strategies to reduce cross-contamination and cross-infection (Fisher et al, 2014), and the particular problems posed by biofilm in terms of antimicrobial resistance (Whitehead and Verran, 2015) , three were selected, determined by staff availability. These were phage therapy, repurposing other drugs containing antimicrobial metals, and the nature of biofilm.

To avoid a mini-lecture format, brief illustrative demonstrations were devised – using 3-D glasses to view models of phage and biofilm, and bioluminescent bacteria (*Escherichia coli* strain DH5a containing a pGLO vector (Bio-rad) expressing Green Fluorescent Protein (GFP) grown in Nutrient Broth supplemented with 0.2% arabinose for GFP induction. Bacterial fluorescence was observed using UV backlights.) to dramatically demonstrate zones of inhibition on agar plates (fig 2), and death (by inactivation of a liquid culture with resultant loss of fluorescence) in the dark space.

Why is AMR an issue and what is being done to address it?

These messages were reinforced throughout the visit, through key points on posters displayed at the stations, and via the presenters and discussion. The Antibiotic Guardian leaflet summarises a range of key points and actions.

Legal requirements and costs

Costs for the event were met directly and indirectly by the University. In terms of personnel time, in addition to two site visits, several planning meetings were held at the University. At the event itself, four Professors, three lecturers, three postgraduates, two nurse observers, and one University coordinator were in attendance, alongside three volunteers from Manchester Science Festival and three members of staff from the museum. Post-event, time was also needed for photography of over sixty agar plates and posting to the FlickrR site.

Equipment costs were small, comprising swabs and agar plates. Travel to and from the venue, parking and an evening meal for University staff was also met by the University.

Public Insurance liability was covered for University staff, and appropriate risk assessments were made for each activity. Key issues were the minimisation of liquid spillage risk (neither liquids nor food are permitted in the tunnels), and any potential infection hazard posed by live microorganisms. The GFP-engineered *E.coli* culture (biosafety level one) was only held by the microbiologists, agar plates were sealed, and a disinfecting agent was available in case of spillage. The tunnels themselves have visitor safety procedures in place. Ethical approval to undertake non-participant observation of the participant groups was obtained from the Faculty of Health, Psychology and Social Care ethics committee at Manchester Metropolitan University .

Logistics and promotion

The event was held as part of Manchester Science Festival 2017, and was advertised (over 18s only) on the festival website as well as on the museum website. The University also promoted it through social media. Attendees registered through Eventbrite, and each paid £10 (museum costs). The minimum number of registrations required was 18. A maximum number of forty was identified, so that groups of ten, each with a guide, could visit the three stations (nursing, swabbing and antimicrobials; a fourth station was unrelated to the AMR topic). A circular route around the tunnels was mapped so that each group encountered all stations and not other groups (to prevent crowding). The time spent at each station was limited to twenty minutes, after which time a whistle was blown and the groups moved on, led by their guides. The sequence of stations therefore varied for each group, but since each activity was free-standing, it was considered that this would not affect visitor experience. The small group size and careful event planning facilitated opportunity for questions and discussion. Indeed, the entire evening was designed to be interactive, informal and friendly. Whilst the location was a particular focus for this event, it is important to consider that event's such as this can be reproduced in any location. If a location with an interesting story/history is available, embedding this into the event may help provide a more well-rounded, engaging event, and can help tailor towards target age range.

Evaluation

There was opportunity for gathering quantitative evidence of engagement via numbers of gingerbread men diagrams handed in, number of agar plates used, and number of FlickrR downloads. Presenters/demonstrators could give some qualitative feedback, but in order to enable them to focus entirely on delivery, additional routes were implemented. The guides were asked to note questions asked by their group at each station. In addition, an observer remained at each station, tasked with recording audience engagement at regular intervals (table 1). Each observer selected their own intervals: activity-focused or time-focused. Observers recorded the number of group

members who demonstrated disengagement, passive engagement, task-orientated engagement, or epistemic engagement (developed from Sadler, Puig et al. 2011). Interest in the 'giant gingerbread man' was also noted.

Results

Quantitative evaluation

The event sold out on Eventbrite. Thirty-seven adults attended the event, typically in pairs or family groups (with adult children). Informal conversation at the shop revealed that several had wanted to visit the museum previously, and this event had provided the trigger (several also expressed a desire to come back). Thirty-five gingerbread men were handed in after the introduction, and the giant gingerbread man presented with 141 marks indicating antibiotics usage, particularly at mouth, nose, throat, lungs and lower torso (fig 3). Several of the visitors examined the figure, but counts were not made.

Sixty-two agar plates were inoculated. The enthusiasm with which the adults scouted the tunnels for exciting locations to swab was remarkable. Images of all plates were posted on Flickr, which was accessed 57 times within one week of posting (and also accessed 22 times within one week of the event before results were posted). In addition to the swabbed samples, settle plates had been set up to demonstrate the extent of aerial contamination (the tunnels were cool, but the air was moist). Plates generally revealed a wide range of different colony morphologies of bacteria and fungi, although there was no evidence of antimicrobial activity. The survey of recognised pathogen names revealed that the only bacterial pathogen visitors had not heard of was *Acinetobacter baumannii* (Fig 4). Of the remaining 12 strains, the most common was *E. coli* (with 16% of responses).

Qualitative observations

Feedback from guides

The guides noted questions asked by the groups (table 2). These revealed a high level of engagement, curiosity and understanding. Informal comments from the guides noted that in general, visitors were absorbed with the hands-on activity, completely engaged with the nursing stories, but occasionally less confident around the more overt research-based science presented in the antimicrobial session, where some terminology and abbreviations were not explained. There was also less time available for questions in this session.

Feedback from observers

Nursing station

Observations were made every five minutes. The observer noted that 'the groups became more interactive as the evening progressed, probably because they had gelled as a group. Questions were insightful and there was engagement with the process right from the start'. In every case, the engagement shifted from passive to epistemic after the first five minutes. Interactive behaviours included eye contact with presenter and other group members, nodding, laughter, discussion and debate.

Swabbing station

Observations were made once at the start of the session, once in the middle and once towards the end. In all four iterations, the visitors progressed from task-orientated engagement through to epistemic engagement, with the observer commenting on the level of ownership the visitors gained when allowed to go and swab an area of the tunnel which they had identified. The observer also noted audience fascination with the antibiotic timeline, and shock at the lack of recent antibiotic drug development.

Antimicrobials station

Observations were noted at five points during the session (introduction, fluorescence, bacteriophage, biofilm, examine liquid culture). Disengagement was noted during the introduction for the second group, and during the bacteriophage and biofilm topics for the fourth group.

Otherwise the engagement was passive for the introduction, predominantly task-orientated for other activities, with some epistemic engagement for most of the research topics.

Discussion

Overall, quantitative and qualitative markers of engagement indicated that this was a successful event, appropriate to the audience satisfying the aims of the delivery team and providing additional benefits for stakeholders. For the venue, previous events have focused on the tunnels themselves, rather than using them as an environment for the delivery of another message. The tunnels deadened sound well, so there was no noise interference from the different stations, and the circular route planning worked well logistically. The museum staff were very positive about the event, and were inspired to investigate other similar activities.

The adult-only nature of the event meant that the audience was free to enjoy and explore the topics: questions were high level, and the interactions between presenters and audience was effective and informal. In particular, the storytelling element at the nursing station enabled humorous and relaxed interaction. Storytelling, if done well (and if not too long - particularly if the audience is standing) is an excellent lure to engagement and an increasingly popular means of engaging audiences with science (McDrury and Alterio, 2003). This event demonstrated that there is no age limit for such an approach. Indeed, literature itself provides an excellent facilitator for discussion between scientists and non-scientists: for example, the book of short stories commissioned by NESTA (<https://www.nesta.org.uk/>) to explore AMR (Infections Futures, <https://www.nesta.org.uk/publications/longitude-prize-infectious-futures>) was recently considered during a meeting of the Bad Bugs Bookclub (<http://www2.mmu.ac.uk/engage/what-we-do/bad-bugs-bookclub/>). Similarly, the swabbing exercise was exceptionally successful: the adults were as excited and enthralled as children to be doing some practical microbiology. 'Doing' and 'creating' is always most appropriate for high-level learning (e.g. Bloom's taxonomy), and again, this approach

appears not to have any upper age boundary, and perhaps should be considered more regularly at adult-only events.

In terms of science-related findings, it was noted that the pattern of infections on the gingerbread man differed from that obtained at a previous family-focused event (Redfern et al., 2018): for the adults, fewer antibiotics were used for throat infections, but more for chest, UTI, knee, hand and foot infections. The simplicity of the gingerbread man outline prevented differentiation of infection of eyes, nose and mouth, genital/urinary, and breast/lungs. Nevertheless, the aim of this exercise was to demonstrate the value of antibiotics for commonly encountered infections (the opportunity was also provided to write if any systemic infections had been treated), and this aim was clearly met. The microorganism which was unknown to the audience was one of the three most critical on the WHO pathogen list. The other two 'critical' pathogens, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae*, both scored the next lowest value with only 1.1% and 2.3% of responses. The most well-known pathogens were *E. coli* (16.2%), *Salmonella spp* (15.1%) and *S. aureus* (11.6%). This observation begs the question as to whether our audiences need to know such information, and if so, how is this information best conveyed.

The antimicrobials station provided a good opportunity for linking research and impact through a public engagement event, but it is important that presenters consider in advance the level of knowledge of their audience, as well as the particular messages they wish to convey. They should also ensure that there is opportunity for questions and audience engagement – whether hands-on or otherwise. There are many opportunities for science communication training in the UK (which could be considered by aspiring (and experienced) communicators).

This event was a first attempt to incorporate qualitative measures of audience engagement as an indicator of impact, coupled with quantitative data, as part of a highly focused event. The evaluation revealed that adult audiences can easily be absorbed into an activity after a brief introduction, enabling high level interaction and learning as well as enjoyment to take place. The use of observers released the presenters from evaluation duties, enabling them to focus on their specific activities.

Although a commonly used tool, a questionnaire was purposely not used to collect visitor feedback, as the team were concerned with 'questionnaire overload', and the appearance the the event 'success' was more important to the delivery team than the enjoyment and education of the visitors, instead opting for an unbiased view of engagement documented *in situ*. Another option, although not implemented in this study, is to attempt to re-engage the visitor at some point in the future to determine any longitudinal impact your event may have had.

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Conflict of interest

There are no conflicts of interest to report

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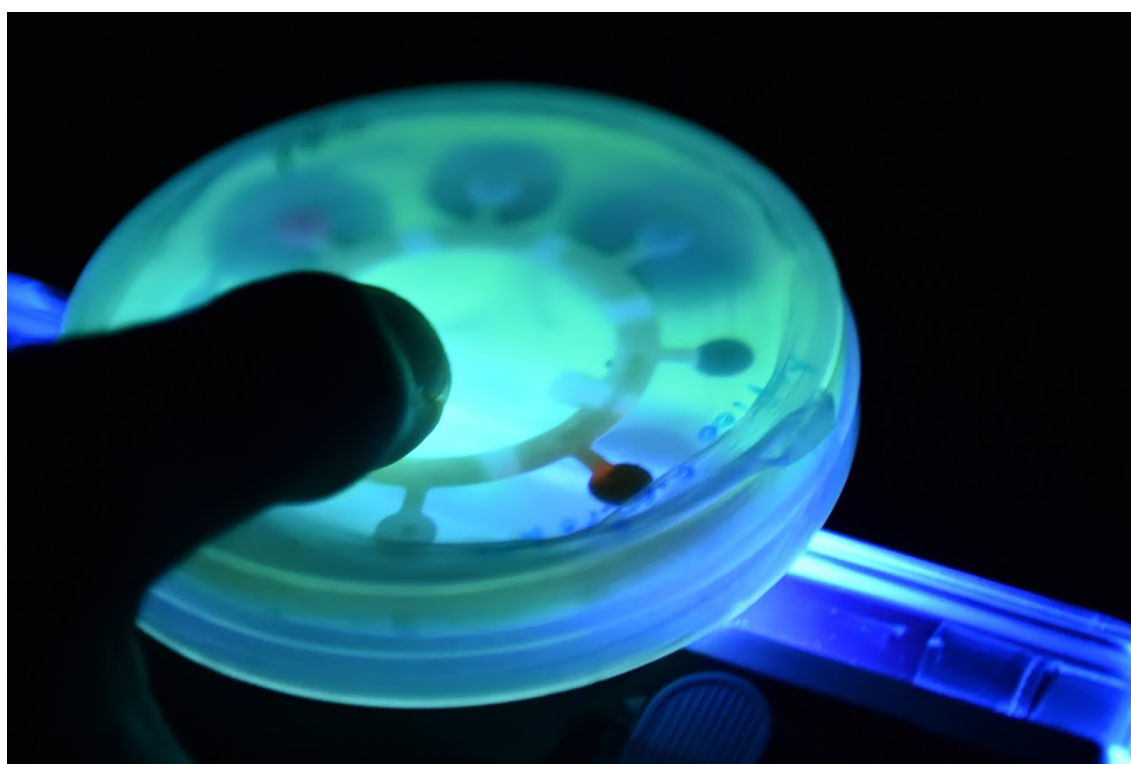
420 Figure 1: Introduction to the event made by museum curator and delivery team leader



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422 Figure 2: Zones of inhibition demonstrated using fluorescence for enhanced visibility in a darkened

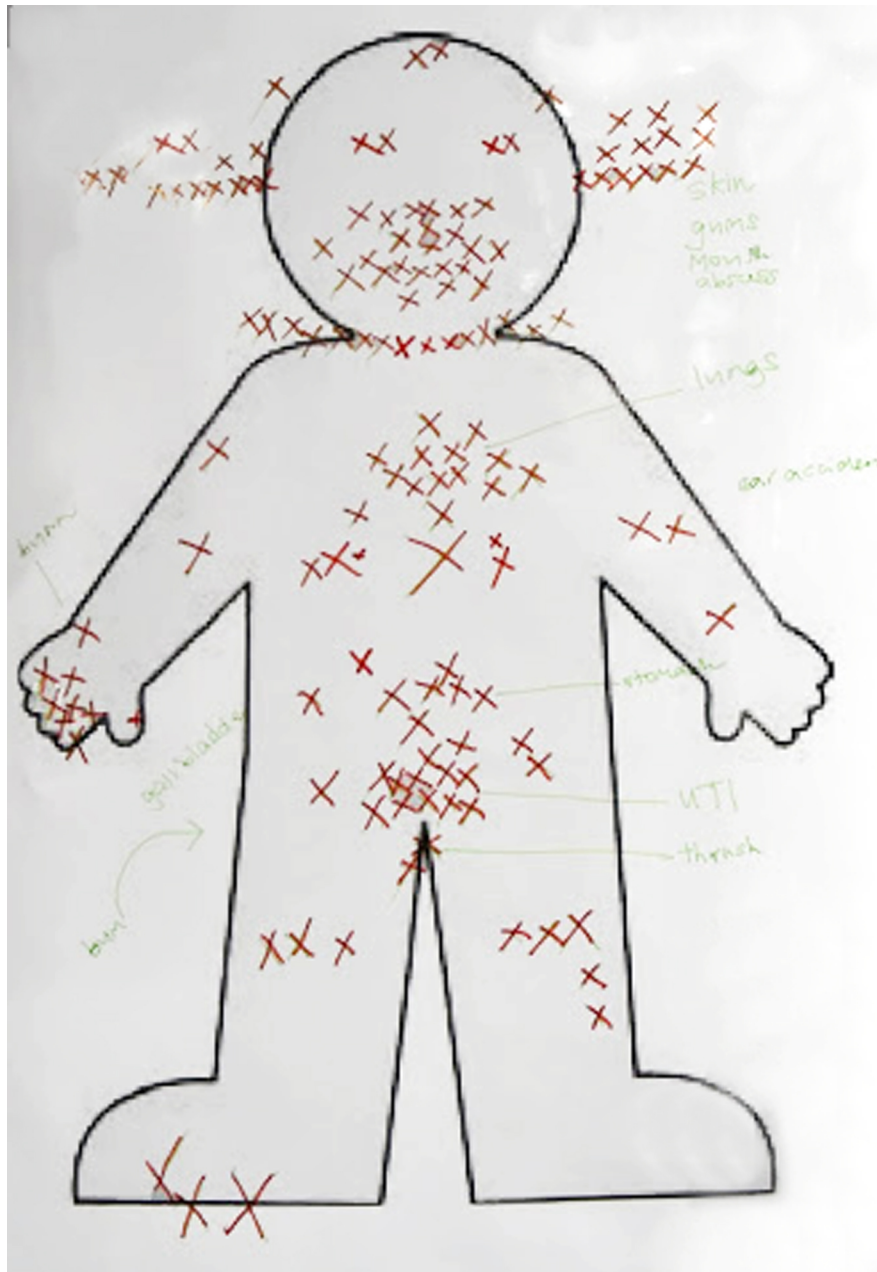
423 space



424

425 Figure 3: 'Gingerbread man' figure: each 'X' represents an infection for which one visitor was

426 prescribed antibiotics. Most visitors had been prescribed antibiotics on several occasions.



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429 Figure 4: Percentage of responses given by visitors to the question 'which of the following pathogens

430 have you heard of? (n=86)

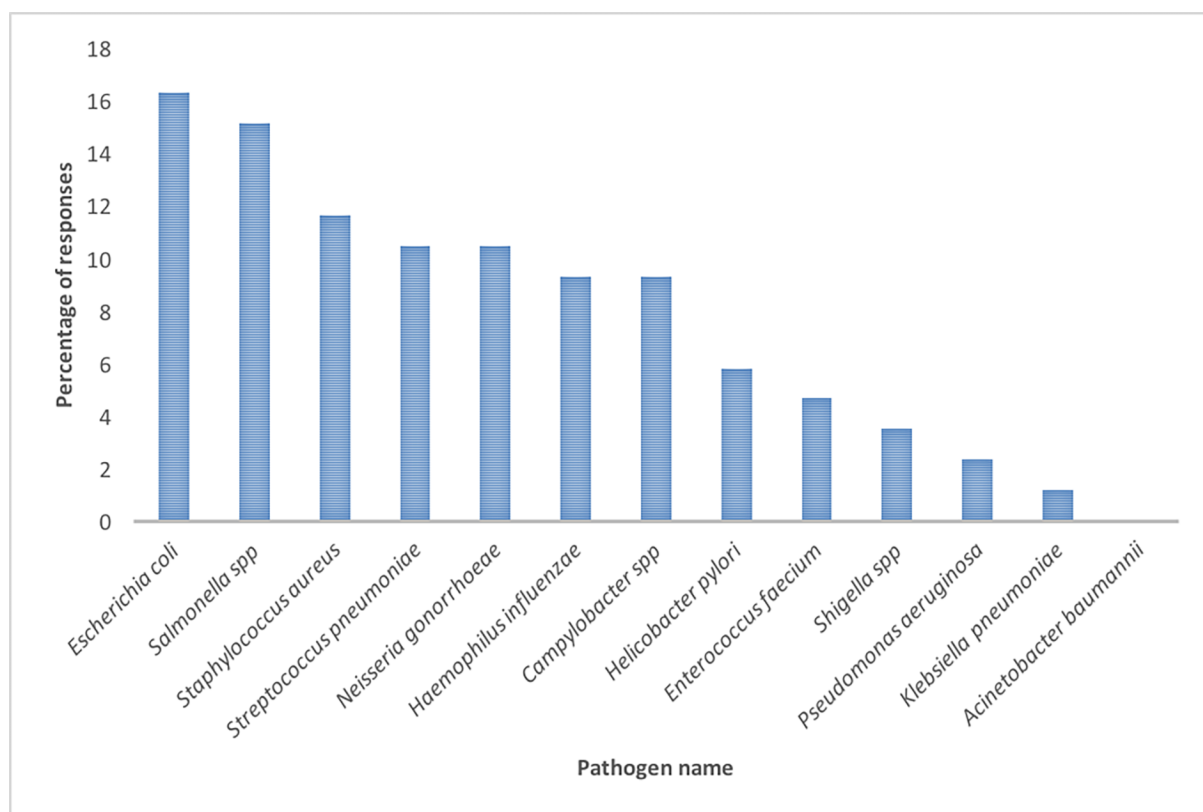


Table 1: Completed table provided to observers, describing behaviour that they were to note. This enabled them to create their own matrices, appropriate to their activity station.

Category	Description	Examples
Disengagement (DE)	Visitors are not focused	Visitors are discussing things not associated with the event. E.g. visitors are using a mobile phone.
Passive engagement (PE)	Visitors receive information	Visitors are paying attention to demonstrator/volunteer. E.g. Listening to instructions on activity.
Task-oriented engagement (TE)	Visitors are engaged in the event – guided by demonstrators	Visitors are actively involved / following a specified instruction from demonstrator.
Epistemic engagement (EE)	Visitors are actively involved in developing ideas and asking questions	Visitors are asking questions and actively involved in the development of research questions and hypotheses. Cognitively demanding.

437 Table 2: Questions asked by the audience at the different stations

438

Nursing	Antimicrobials	Swabbing
Was it only penicillin available during World War 2, or were any other antibiotics available?	How are those kind of drugs administered?	When we were young we didn't need hand gel.
If someone was at 'death's door', would antibiotics still have been effective?	Is resistance affected by metal export?	General questions around who owns/manages the database of bacteria compiled from swabs sent by the public, to be used for the detection of new antibiotics
Would antibiotics only have been made available for civilians if it was a last option/extreme situation? (question asked in context of military – including PoWs – being prioritised for antibiotics due to shortage of available supplies)	How close are you to getting there? (finding an alternative)	I notice mould grows really quickly on cream cheese – it tends to be pink coloured. I have heard that the pink mould is dangerous. Is that true?
It's interesting that antibiotics, during WW2, were considered a 'last resort' treatment, when they are now considered a first line of treatment (person commented that they are a teacher and lots of children are having antibiotics for minor ailments as parents have expectation of treatment from doctors).	How do you stop phage killing the bacteria you want?	General technical questions about swabbing (where to swab).
Did nurses/doctors observe penicillin allergies when penicillin first came into use?	Where do you get your bacteriophage from? Do you keep the samples?	
I use tea tree oil and find it stops most infectious in their tracks, so never get to the point where I need a prescribed antibiotic – will we be exploring natural alternatives to antibiotics during this event?	Do you think that people will accept these alternatives?	
When was penicillin/antibiotic resistance first noted?	Do you look at phage DNA?	
How did penicillin start getting exported around the world? Did we give it to the Soviets?		

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